Does Foreign-Exchange Intervention Matter? The Portfolio Effect

By KATHRYN M. DOMINGUEZ AND JEFFREY A. FRANKEL*

Until recently, there was an unusual degree of consensus among economists that intervention by central banks in the foreign-exchange market did not offer an effective or lasting instrument for affecting the exchange rate, at least not independently of monetary policy. This consensus was largely shared among policymakers and participants in the financial markets as well. The 1982 G-7 economic summit at Versailles commissioned a study of intervention, known as the Jurgenson report, which found that the effects were small and transitory at most.[1]

We think that the time is ripe for new statistical testing of the question. Many policymakers and foreign-exchange traders believe that the intervention operations that have taken place since the Plaza Agreement of September 1985 have had an effect, especially when operations are coordinated. Moreover, the theoretical case against the effectiveness of intervention is not as clear as a reading of the economics literature might suggest.

The academic literature is predicated on the distinction between intervention operations that are sterilized and those that are allowed to affect the money supply. We study the intervention operations that actually took place between 1982 and 1988, regardless of whether they were sterilized. However, we do begin in Section I with a review of the issues involved.[2]

There are two possible channels through which intervention (whether sterilized or not) can influence the foreign-exchange rate: the portfolio and the expectations channels. Intervention can, even if sterilized, influence exchange rates through the *portfolio channel*, provided foreign and domestic bonds are considered imperfect substitutes in investors' portfolios. Intervention operations that, for example, increase the current relative supply of mark to dollar assets which private investors are obliged to accept into their portfolios, will force a decrease in the relative price of mark assets.[3] Intervention can also influence exchange rates, regardless of whether foreign and domestic bonds are imperfect substitutes, through the *expectations channel*. The public information that central banks are intervening in support of a currency (or are planning to intervene in the future) may, under certain conditions, cause speculators to expect an increase in the price of that currency in the future. Speculators react to this information by buying the currency today, bringing about the change in the exchange rate today.

In Sections II and III we describe the econometric problems that arise in the standard portfolio-balance estimation equation. We derive an alternative portfolio-balance

*Dominguez: Kennedy School of Government, Harvard University, 79 J. F. Kennedy Street, Cambridge, MA 02138; Frankel: Department of Economics, University of California, 787 Evans Hall, Berkeley, CA 94720. We thank three anonymous referees for valuable comments and suggestions; Julia Marsh and Julia Lowell for research assistance; and Franz Scholl at the Bundesbank, Jean-Pierre Roth at the Swiss National Bank, and officials at the U.S. Treasury and the Board of Governors of the Federal Reserve System for making the daily intervention data available.

[1]Many of the econometric results, finding little or no effect, were reported in Kenneth S. Rogoff (1984) and Dale W. Henderson and Stephanie Sampson (1983).

[2]For authoritative statements, see Henderson (1984) or Maurice Obstfeld (1990).

[3]The exchange-rate reaction to an increase in the relative supply of outside foreign assets may be reduced if there is an increase in their expected rate of return that induces a corresponding increase in demand.

specification that measures the expected change in exchange rates using survey data rather than *ex post* exchange-rate changes. We also take account of potential simultaneity bias by using instrumental-variable estimation. The expectations channel suggests that public information (available from the financial press) on intervention operations can serve as an instrument for official intervention. In Section IV we present the instrumental-variable estimates of our portfolio-balance equation. The empirical work was made possible by agreements with the U.S. Board of Governors of the Federal Reserve System, the German Bundesbank, and the Swiss National Bank, allowing use of previously unavailable daily intervention data over the period 1982–1988.[4] In Section V we present our conclusions.

I. The Standard Theory: Sterilized versus Nonsterilized Intervention

There are three standard arguments as to why the effects of intervention should be very small: the small size of intervention relative to the total market, Ricardian equivalence, and high international-asset substitutability. The latter two, if valid, imply that the effects of sterilized intervention should be small or zero. The first implies that the effects of intervention should be relatively small even if nonsterilized.

While the scale of intervention operations in recent years is unprecedented, it remains small relative to the stocks or flows in the foreign-exchange market. The total net stocks of currencies that could in theory be brought into the foreign-exchange market at any time are enormous. U.S. M2 money supply (as defined by the Federal Reserve), for example, currently exceeds $3,000 billion. By comparison, the average coordinated intervention operation in support of the dollar during the period from January 1985 to December 1988 involved $278.5 million, while the average coordinated sale of dollars involved $373.2 million.

Standard models of exchange-rate determination indicate that a nonsterilized intervention influences an exchange rate in proportion to the change in the relative supplies of domestic and foreign money, just as any other form of monetary policy does. The idea that *sterilized* intervention operations have any effect at all, on the other hand, is less accepted. Those who believe sterilized intervention to have no effect base their arguments either on "Ricardian equivalence" or on the high substitutability between foreign and domestic bonds. We consider these two arguments in turn.

If government bonds entail a public liability of future taxation to service them, and if investors look far into the future, optimize intertemporally, and internalize the welfare of future generations, then government bonds are not true "outside" assets. If government bonds are not true outside assets, it follows that swaps in their currency composition have no effect on the foreign-exchange market equilibrium (Frankel, 1979). There are many arguments against Ricardian equivalence, both theoretical and empirical; it is the sort of proposition that one would like to test rather than impose.

Even if it is granted that government bonds are outside assets, the second line of argument against the effectiveness of sterilized intervention is that domestic and foreign bonds are perfect substitutes, so that changes in their relative supply have no effect. A less extreme version of the argument is that substitutability is very high, even if not literally infinite, so that intervention (in the relevant magnitudes) can have very little effect quantitatively. One point that is often missed is that, even if it is true that the effect of large-scale sterilized intervention on the differential in rates of return is very close to zero, the effect on the *level* of the exchange rate may be relatively large. As long as changes in bond supplies matter, they should have a proportionate effect on the exchange rate (which is the relative price of foreign bonds in the portfolio model, not

[4] With the understanding that the Bundesbank data be used under certain restrictions.

just the relative price of money) in the absence of changes in the risk premium, no matter how high the degree of substitutability (Frankel, 1985 pp. 213–15).[5]

Even for those who hold either to Ricardian equivalence or to the assumption that foreign and domestic bonds are perfect substitutes, there remains a channel through which sterilized intervention can have an effect on exchange rates. Intervention operations can affect exchange rates through the *signaling channel* if they are used by central banks as a means of conveying (or signaling) to the market inside information about future monetary policy. If market participants believe central-bank intervention signals, then, even though today's money supply has not changed, expectations of future monetary policy will change. When the market revises its expectations of future money supplies, it also revises its expectations of the future spot exchange rate, which brings about a change in the current rate. The signaling channel is thus one example of the expectations channel mentioned in the Introduction.[6]

It is known that daily intervention by the Federal Reserve Bank of New York is fully and automatically sterilized: the foreign-exchange trading room immediately reports its dollar sales to the open-market trading room, which then buys that many fewer bonds, so that the daily money supply is precisely what it would have been if no intervention had occurred. This leaves open the possibility that a Federal Reserve Board decision to try to influence the exchange rate will result in both intervention and a different money supply, say, on a monthly basis. The Bundesbank and other smaller central banks are less prone to complete sterilization than are the U.S. authorities. To the extent that the market learns about central banks' future monetary-policy intentions by observing intervention, the signaling hypothesis is confirmed.[7] To summarize, sterilized intervention could have an effect on the exchange rate either if domestic and foreign bonds are imperfectly substitutable outside assets or if public knowledge of intervention today alters expectations of future policy. These possibilities are empirical questions and are tested in this paper.

II. The Portfolio-Balance Channel

The portfolio-balance theory says that investors diversify their holdings among domestic and foreign assets—including bonds, if we do not rule them out a priori on the grounds of Ricardian equivalence—as functions of expected rates of return. Measuring the expected rates of return requires data on interest rates, which are readily available, and data on investors' expectations of exchange-rate changes, which are not. Some early tests assumed away this problem by setting expected depreciation equal to zero and simply looking for a relationship between the level of the exchange rate and the supplies of domestic and foreign assets (e.g., William H. Branson et al., 1977).[8] Even aside from the expectations problem, these studies were plagued by a second econometric difficulty: simultaneity.

A regression specification that avoids this simultaneity problem takes the dependent variable to be the differential in expected *rates of return* between domestic and foreign assets, rather than the *level* of the exchange rate, and uses *ex post* changes in the exchange rate to measure investors' ex-

[5]Once one takes into account effects on the expected future rate of change in the exchange rate, the exchange-rate effect of a 1-percent change in the relative supply of foreign assets could be either more or less than 1 percent.

[6]An influential statement is Michael Mussa (1981); see also Dominguez (1990, 1992 Ch. 2).

[7]Trying to test the signaling hypothesis by observing what happens to the money supply *ex post*, in finite samples, would be a problematic way of approaching the question. Intervention is at best only one of many factors relevant for determining the future money supply; in finite samples the relationship might not be detectable.

[8]A more recent attempt, with better measures of asset supplies, is Stephen S. Golub (1989).

pectations by invoking the methodology of rational expectations (Frankel, 1982a; Michael Dooley and Peter Isard, 1982). Begin by considering the asset-demand function that determines the portfolio share x that is allocated to mark assets as a function of the risk premium, rp:

$$(1) \qquad x_t = a + b\,\mathrm{rp}_t$$

where $\mathrm{rp}_t = i^{\mathrm{DM}}_{t,k} - i^{\$}_{t,k} + \Delta s^{\mathrm{e}}_{t,k}$, $i^{\mathrm{DM}}_{t,k}$ is the k-period-ahead euroDM interest rate, $i^{\$}_{t,k}$ is the k-period-ahead eurodollar interest rate, and $\Delta s^{\mathrm{e}}_{t,k}$ is the expected k-period-ahead change in the log of the dollar/mark (\$/DM) spot exchange rate. The portfolio share, x_t, is defined as $x_t = S_t M_t / W_t$ where S_t is the \$/DM spot exchange rate, M_t is the total quantity of mark assets in investors' portfolios (denominated in marks), and W_t is total wealth (denominated in dollars). Now invert the equation to express the risk premium as a function of the aggregate supplies of assets that must be held in market equilibrium:

$$(2) \qquad \mathrm{rp}_t = -ab^{-1} + b^{-1}x_t.$$

If domestic and foreign assets are perfect substitutes, then b is infinite, the coefficient b^{-1} in equation (2) is zero, and changes in asset supplies have no effect on the risk premium. If investors have rational expectations, the *ex post* change in the exchange rate, $\Delta s_{t,k}$, can be substituted for the expected change because the only difference is a forecast error, $\varepsilon_{t,k}$, that is independent of x_t (and of all other variables that are contemporaneously observable). We can run a regression on the resulting equation:

$$(3) \qquad i^{\mathrm{DM}}_{t,k} - i^{\$}_{t,k} + \Delta s_{t,k} = -ab^{-1} + b^{-1}x_t + \varepsilon_{t,k}.$$

The regression estimate of the coefficient b^{-1} in equation (3) is generally found to be insignificantly different from zero, a failure to reject the joint null hypothesis of perfect substitutability and rational expectations.[9] One possible explanation for this result is that there is insufficient power in the test. One way of bringing additional information to bear is to assume that investors choose their portfolio allocation, x_t, to optimize a function of the mean and variance of end-of-period wealth, from which it follows that equation (1) holds with a constraint imposed: the coefficient is inversely proportionate to v, the variance of the return differential (Pentti J. K. Kouri and Jorge A. Braga de Macedo, 1978; Frankel, 1982b; Michael Adler and Bernard Dumas, 1983; Rudiger W. Dornbusch, 1983; Branson and Henderson, 1985). In the case where goods prices are nonstochastic, v is simply the variance of exchange rate changes, and a, the minimum-variance portfolio, is closely related to the share of German goods in the consumption basket of the investor. The inverted form, equation (3), becomes

$$(4) \qquad i^{\mathrm{DM}}_{t,k} - i^{\$}_{t,k} + \Delta s_{t,k} = -a(rv) + (rv)x_t + \varepsilon_{t,k}$$

where we have defined r to be the constant of proportionality, which is the coefficient of relative risk-aversion.[10]

The rational-expectations methodology assumes that the regression error and fore-

[9]At least that is what studies find when asset supplies (x_t) are computed to include not only foreign-exchange intervention, but also government budget deficits and other forms of asset creation that usually dwarf intervention in magnitude (e.g., Frankel, 1982a; Dooley and Isard, 1983; Paul Boothe et al., 1985). Studies that focus more narrowly on daily changes in asset supplies through foreign-exchange intervention do sometimes find an effect on the differential in rates of return (see Bonnie Loopesko, 1984; Dominguez, 1990).

[10]This is the simplified form of the equation in Dornbusch (1983), where a is interpreted as equal to the share of German goods in the consumption basket of the investor in question. Paul R. Krugman (1981) pointed out that a correct treatment of the convexity term that arises from Jensen's inequality makes the constant term $-(ra - a + 1/2)v$, instead of $-a(rv)$. In what follows, the variable in the regression is v in either case, and it is only the interpretation of its coefficient that is affected.

cast error are identical, so that the equation can be estimated subject to the constraint that the coefficient is proportionate to the variance of the error term. The constraint of mean-variance optimization imposes overidentifying restrictions either when the parameter a is estimated from consumption-share data, when the list of countries' assets is expanded beyond two so that v becomes a variance-covariance matrix, or when v is allowed to vary over time. Despite the presumed increase in power, the empirical literature generally fails to reject the null hypothesis of perfect substitutability, which is now interpreted as risk-neutrality ($r = 0$) (Frankel, 1982b). This finding is the same when the variance, v, is allowed to vary over time, as in the popular ARCH models (Charles M. Engel and Anthony P. Rodrigues, 1989; Alberto Giovannini and Philippe Jorion, 1989).

III. Market Expectations

There is an econometric difficulty, one that arises in estimating equation (4), concerning the measurement of the expectations variable in the risk premium. Even if the rational-expectations methodology is valid (i.e., the forecast error, $\varepsilon_{t,k}$, is uncorrelated in-sample with all other contemporaneous variables), there is the undeniable problem that the magnitude of the error term is extremely large. This could lead to low power—a failure to reject risk-neutrality even though the coefficient of risk-aversion is, in reality, greater than zero. Furthermore, there is reason to think that *ex post* changes in the exchange rate are a particularly bad measure of what investors expected *ex ante*. Independent estimates of market forecasts of exchange rates, drawn from survey data, suggest that expected depreciation varies closely with the forward discount, while *ex post* changes in the exchange rate do not and tend, if anything, to lie in precisely the opposite direction (Kenneth A. Froot and Jeffrey A. Frankel, 1989). We choose to measure expectations by using the survey data rather than *ex post* changes, on the grounds that (a) the evidence of bias is damaging for the latter and (b) the magnitude of the measurement error is almost certainly larger for *ex post* changes than for the survey data.

A number of different surveys at different horizons are available. We use here the four-week-ahead survey forecasts conducted by Money Market Services, International (MMS) for the period from October 24, 1984 to December 30, 1988.[11] Unlike some other surveys, it is conducted on a weekly basis (since July 1985; before that it was conducted every two weeks). In addition, we report results for an earlier period from November 17, 1982 to October 10, 1984, when the survey was conducted every two weeks and pertained to three-month-ahead forecasts. One might expect that intervention would have a greater effect in the later period, because the Reagan Administration's firm commitment to free-floating began to change when Donald Regan and Beryl Sprinkel were succeeded at the Treasury by James Baker and Richard Darman in January 1985 and when the Plaza Agreement followed in September.

Our alternative portfolio-balance specification with the expected change in exchange rates measured using survey data is

$$(5)\quad i_{t,k}^{\mathrm{DM}} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{\mathrm{e}} = \beta_0 + \beta_1 v_t + \beta_2 v_t x_t + u_{t,k}$$

where $\Delta\hat{s}_{t,k}^{\mathrm{e}}$ is the expected change in the spot rate between period t and $t+k$ measured by the survey data, $\beta_1 = -ar$, $\beta_2 = r$, and the error term, $u_{t,k}$, is now meant to reflect any measurement error in the data, rather than investors' forecasting errors. In light of the many studies concluding that exchange-rate changes have variances that are autocorrelated over time, we estimate the variance, v_t, as the daily variance of exchange-rate changes between survey dates. To our knowledge, survey data have not been used together with data on asset

[11] These data were introduced in another context by Dominguez (1986) and Frankel and Froot (1987).

supplies and variances to estimate a risk-premium equation.

Ordinary least-squares (OLS) estimation of equation (5) will be appropriate if all measurement error is in the survey data. However, if the asset data are measured with error or if asset demands are given by the mean-variance specification plus an error term, then the regression will be subject to simultaneity bias, and (5) should be estimated using instrumental variables (IV). We estimate equation (5) using instrumental variables on the premise that simultaneity bias is likely to be a problem. The variables we use as instruments are constructed from news appearing in the financial press about changes in the Fed's or Bundesbank's exchange-rate policy since the last survey date. The first instrumental variable, NEWS_t, is set equal to $+1$ if there were newspaper reports of official exchange-rate policy announcements in support of the dollar (including, for example, announcements of G-7 meetings to deal with dollar weakness), -1 if there were official announcements against the dollar, and 0 if there were no such announcements. The NEWS variable excludes reports of intervention policy. The second instrumental variable, REPINT_t, is set equal to $+1$ if there were newspaper reports of central-bank intervention in support of the dollar, -1 if there were reports of intervention against the dollar, and 0 if there were no such reports. These measures of news about policy changes tend to be exogenous and unpredicted. The instrumental variables should, therefore, be correlated with the spot rate and actual asset supplies while remaining uncorrelated with the error term in equation (5). Indeed, the coefficients on the instruments are highly significant in the first-stage regression.

Charles R. Nelson and Richard Startz (1990) suggest that, in the case of multiple explanatory and instrumental variables, high first-stage R^2's do not insure against spurious IV regression inference. Because the bias of OLS may be smaller than that of IV if the feedback from the risk premium to intervention is strong, we also report some of the OLS estimates of equation (5) in the tables presented in the following section.

The second channel whereby intervention may influence exchange rates, in addition to the portfolio channel, is the expectations channel. It is operative only if the market is aware of central-bank intervention operations. Neither the Fed nor the Bundesbank publicly announces intervention activities contemporaneously. It is likely that some intervention operations remain secret. In Dominguez and Frankel (1993a table 6.2), we find that approximately 80 percent of actual intervention operations are picked up by the press. There we report explicit estimates of the (statistically significant and large) effects of the news reports on the expectations of market participants and on the spot rate itself. In the appendix to Dominguez and Frankel (1993a) we also provide a summary of the newspaper reports of exchange-rate policy from which we created the two dummy variables.

IV. The Estimation Results

The instrumental-variable estimates of the portfolio effect, equation (5), for the dollar/mark risk premium, are presented in Tables 1 and 2. The intervention variable (defined as x_t in the text) is measured in the tables as a percentage of total wealth.[12] Wealth, W_t, is measured as the total supply of U.S. and German federal government debt that has been issued and so must be held in investors' portfolios.[13] The daily intervention data provided by the central

[12]Estimates of equation (5) with intervention measured in millions of dollars, rather than as a percentage of total wealth, are available in Dominguez and Frankel (1993b tables 16.3 and 16.4). The estimated coefficients on both the variance and intervention variables are qualitatively similar (in terms of statistical significance) to those reported here.

[13]The U.S. wealth proxy is from various issues of the *Treasury Bulletin* (table FD-1: summary of federal debt, "Total Securities Held by the Public"). The German wealth proxy is from various issues of Deutsche Bundesbank *Monthly Report, VII, Public Finance* (table 9: Indebtedness of the Federal Government, "Total") and was translated into dollars using end-of-month IFS exchange rates. Both data series were converted from monthly to weekly series using linear extrapolation.

TABLE 1—BIWEEKLY THREE-MONTH-AHEAD RISK-PREMIUM EQUATION (SAMPLE: NOVEMBER 1982–OCTOBER 1984)

$$i_{t,k}^{\mathrm{DM}} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t x_t + u_{t,k}$$

(Instruments: NEWS_t, REPINT_t)

Coefficient	Intervention: One-day[a]	Intervention: Two-week[b]	Intervention: Cumulative[c]
A. *Fed and Bundesbank Intervention Included in* x_t:			
β_0	0.009 (0.004)*	0.009 (0.004)*	0.006 (0.003)†
β_1	−29.414 (57.324)	−40.692 (59.879)	379.336 (114.945)**
β_2	3,542.750 (9,985.341)	−107.899 (845.643)	626.214 (145.494)**
ρ	0.626 (0.196)**	0.624 (0.203)**	0.282 (0.365)
DW:	2.16	2.15	1.95
R^2:	0.41	0.41	0.38
B. *Only Bundesbank Intervention Included in* x_t:			
β_0	0.009 (0.004)*	0.009 (0.004)*	0.006 (0.003)†
β_1	−55.013 (61.489)	−38.274 (60.584)	379.794 (113.241)**
β_2	−10,852.20 (21,127.040)	23.917 (908.781)	655.648 (149.214)**
ρ	0.642 (0.190)**	0.633 (0.198)**	0.267 (0.402)
DW:	2.15	2.16	1.95
R^2:	0.40	0.42	0.38
C. *Only Fed Intervention Included in* x_t:			
β_0	0.009 (0.004)*	0.009 (0.004)*	0.007 (0.004)
β_1	−27.376 (55.542)	−44.542 (47.667)	376.248 (181.149)*
β_2	−14,638.35 (25,150.980)	−6,663.846 (8,435.426)	13,539.500 (5,610.806)*
ρ	0.615 (0.203)**	0.644 (0.191)**	0.565 (0.363)
DW:	2.17	2.17	2.09
R^2:	0.41	0.40	0.29

Notes: Standard errors are given in parentheses. The coefficient on $v_t x_t$ (β_2) and its corresponding standard error are divided by 100 for readability. Entries for ρ report the estimated first-lag correlation coefficient. Number of observations = 55; $k = 90$. Intervention is expressed as a percentage of wealth.

[a]Intervention variable is measured at the end of the day prior to the survey.

[b]Intervention variable is an accumulated measure between survey forecasts.

[c]Intervention variable is an accumulated measure from the beginning of the sample period.

†Statistically significant at the 10-percent level.

*Statistically significant at the 5-percent level.

**Statistically significant at the 1-percent level.

banks measure official net purchases or sales of dollars in the foreign-exchange market. Central-bank interest payments and receipts on reserve assets are not included in the data. Intervention is measured in three ways in these regressions. "One-day" intervention is Fed and Bundesbank purchases of dollars on the day before the survey. "Two-week" or "one-week" intervention is cumulated between survey dates, so that it measures total Fed and Bundesbank dollar purchases since the last survey. "Cumulative" intervention is cumulated from the beginning of the sample period and therefore measures the relative stock supplies of outside assets denominated in dollar and mark currencies. We also disaggregate the intervention variable by including Fed and Bun-

TABLE 2—WEEKLY ONE-MONTH-AHEAD RISK-PREMIUM EQUATION (SAMPLE: OCTOBER 1984–DECEMBER 1988)

$$i^{\mathrm{DM}}_{t,k} - i^{\$}_{t,k} + \Delta\hat{s}^{e}_{t,k} = \beta_0 + \beta_1 v_t + \beta_2 v_t x_t + u_{t,k}$$

(Instruments: NEWS_t, REPINT_t)

Coefficient	Intervention: One-day[a]	One-week[b]	Cumulative[c]
A. *Fed and Bundesbank Intervention Included in* x_t:			
β_0	0.001 (0.002)	0.002 (0.001)	0.002 (0.002)
β_1	57.399 (18.529)**	42.164 (14.037)**	231.559 (74.438)**
β_2	6,000.177 (2,502.075)*	1,464.781 (580.168)*	180.809 (65.347)**
ρ	0.297 (0.200)	0.327 (0.215)	0.389 (0.211)†
DW:	2.12	2.12	2.17
R^2:	0.06	0.13	0.12
B. *Only Bundesbank Intervention Included in* x_t:			
β_0	0.002 (0.002)	0.003 (0.001)†	0.001 (0.001)
β_1	40.039 (14.196)**	33.844 (13.042)**	461.932 (115.108)**
β_2	6,313.085 (3,086.048)*	1940.330 (944.745)*	427.283 (112.087)**
ρ	0.338 (0.178)†	0.331 (0.200)†	0.304 (0.447)
DW:	2.15	2.13	2.11
R^2:	0.13	0.15	0.09
C. *Only Fed Intervention Included in* x_t:			
β_0	0.001 (0.001)	0.002 (0.002)	0.002 (0.002)
β_1	53.239 (20.998)*	42.451 (14.688)**	73.241 (22.761)**
β_2	8,125.240 (5,098.826)	2,168.151 (1,115.875)†	400.618 (175.468)*
ρ	0.329 (0.177)†	0.353 (0.194)†	0.482 (0.182)**
DW:	2.14	2.14	2.25
R^2:	0.08	0.13	0.05

Notes: Standard errors are given in parentheses. The coefficient on $v_t x_t$ (β_2) and its corresponding standard error are divided by 100 for readability. Entries for ρ report the estimated first-lag correlation coefficient. Number of observations = 185; $k = 30$. Intervention is expressed as a percentage of wealth.

[a] Intervention variable is measured at the end of the day prior to the survey.

[b] Intervention variable is an accumulated measure between survey forecasts.

[c] Intervention variable is an accumulated measure from the beginning of the sample period.

†Statistically significant at the 10-percent level.

*Statistically significant at the 5-percent level.

**Statistically significant at the 1-percent level.

desbank intervention separately. The three separate sets of regressions, therefore, include intervention measured as the sum of Bundesbank and Fed intervention, intervention by the Bundesbank, and intervention by the Fed.

Although there is little reason to suspect that the daily intervention time series are nonstationary, it is possible that the cumulated intervention time series follows a unit-root process. We test for the presence of unit roots in the cumulated intervention time series using the standard and augmented David Dickey and Wayne Fuller (1979) tests as well as the Peter K. Phillips and Pierre Perron (1988) test and the Bayesian odds-ratio test proposed by Christopher A. Sims (1988). We include both a constant term and a time trend in the Dickey-Fuller and Phillips-Perron tests. All three tests decisively reject the hypothesis that the cumulated combined Fed and Bundesbank intervention time series has one or two unit roots. We cannot reject the hypothesis that the cumulated unilateral Fed intervention time series contains a single unit root using either the Dickey-Fuller or Phillips-Perron test criteria at the 0.05 level. However, the Bayesian odds-ratio test indicate a weak rejection of the unit-root hypothesis. We conclude from this evidence that, with the possible exception of cumulative unilateral Fed intervention, our cumulative intervention measure is a legitimate right-hand-side variable.

In the regressions presented in the tables we measure the first explanatory variable in equation (5), the variance of spot changes, between survey dates. In order to test whether the regression results are sensitive to this specification, we also measure the variance term over the risk-premium term horizon. In Table 1 the term horizon is three months, and in Table 2 the term horizon is one month. The regression results using the alternative measures of variance indicate that the time horizon over which the variance is measured has little influence on the coefficient estimates. The variance term is significant in the early period only in the regressions where intervention is cumulative. However, over the latter subperiod, the coefficient on the variance of spot changes is statistically significant in all the regressions. These results are presented in Table 2.

Our primary focus is the estimated coefficient on the intervention variable in the portfolio-balance equation. In the IV regressions over the main period of interest, October 1984–December 1988, the coefficient on intervention is generally statistically significant, regardless of how it is measured. (In the earlier sample period, only cumulative intervention is significant.) The finding that the instrumented coefficients on the Fed and Bundesbank intervention variables are statistically significant in equation (5) implies that intervention, even if sterilized, has an effect. If mark and dollar assets were perfect substitutes, then the coefficient should be zero: changes in asset supplies would have no effect on the risk premium.

In order to check that the results reported in the tables are robust, equation (5) was reestimated (a) using OLS, (b) excluding outliers, (c) without the multiplicative variance constraint, and (d) using intervention data from the Swiss National Bank.

The OLS estimates of the portfolio-balance equation are presented in Table 3. The magnitudes of the OLS coefficients are generally half those of the corresponding IV estimates, but with the exception of cumulative unilateral Fed intervention, the coefficients are statistically significant and correctly signed. It is reassuring that the two sets of estimates are qualitatively similar.

In order to examine the influence of outliers on the results, we searched for regression residuals from equation (5) that were greater than 2.5 times the standard error of the regression estimate. Over the full sample period, two observations met the criterion: September 25, 1985 (the second trading day after the Plaza Accord) and March 5, 1986. In regressions excluding the two outlying observations the coefficient estimates on the intervention variable in (5) are virtually identical to those reported in the tables. The coefficient estimates on the variance terms, however, decrease in size and are statistically significant only when intervention is cumulated from the beginning of the sample period.

In a third set of tests we examine the sensitivity of the reported results to the mean-variance specification by reestimating (5) without constraining the variance and intervention to enter multiplicatively. The estimated coefficients on the intervention variables are qualitatively identical (in terms of statistical significance) to those reported in the tables over both sample periods.[14]

In Table 4 we present estimates of equation (5) using intervention data from the

[14]Regression results excluding outliers and the multiplicative variance constraint are available in tables 16.5 and 16.6, respectively, of Dominguez and Frankel (1993b).

TABLE 3—OLS ESTIMATES OF THE RISK-PREMIUM EQUATION

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta \hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t x_t + u_{t,k}$$

	Sample	
	1982–1984[a]	1985–1988[b]
A. *Fed and Bundesbank Intervention Included in* x_t:		
β_0	0.007 (0.002)*	0.002 (0.001)
β_1	177.797 (74.005)*	110.688 (39.951)**
β_2	301.427 (89.999)**	71.893 (34.207)*
ρ	0.445 (0.135)**	0.382 (0.069)**
DW:	2.03	2.17
R^2:	0.49	0.17
B. *Only Bundesbank Intervention Included in* x_t:		
β_0	0.007 (0.003)*	0.002 (0.001)
β_1	179.587 (73.462)*	195.949 (56.921)**
β_2	319.079 (93.006)**	164.950 (54.997)**
ρ	0.435 (0.136)**	0.337 (0.071)**
DW:	2.02	2.14
R^2:	0.50	0.19
C. *Only Fed Intervention Included in* x_t:		
β_0	0.008 (0.004)*	0.002 (0.001)
β_1	111.252 (77.645)	37.016 (13.872)**
β_2	4,417.309 (2,267.199)†	58.134 (70.751)
ρ	0.595 (0.118)**	0.397 (0.069)**
DW:	2.13	2.19
R^2:	0.45	0.15

Notes: Standard errors are in parentheses. The coefficient on $v_t x_t$ (β_2) and its corresponding standard error are divided by 100 for readability. Entries for ρ report the estimated first-lag correlation coefficient. Cumulative intervention is expressed as a percentage of wealth.

[a]Bi-weekly observations; number of observations = 55, $k = 90$.

[b]Weekly observations; number of observations = 185, $k = 30$.

†Statistically significant at the 10-percent level.

*Statistically significant at the 5-percent level.

**Statistically significant at the 1-percent level.

Swiss National Bank (SNB). The Fed and the Bundesbank are two of the more economically powerful central banks; this additional set of tests allows us to examine whether operations by a smaller central bank are equally as effective. Our choice of countries and sample period was dictated by the availability of daily intervention data. The sample period in Table 4 is January 1987–December 1989 because the SNB was not an active participant in the foreign-exchange market until 1987. It is not appropriate in the Swiss case to construct instrumental variables analogous to those used for the United States and Germany because Swiss intervention policy is contemporaneously publicly available. The OLS regression results presented in Table 4 indicate that only when Fed and SNB intervention are combined is the variable statistically significant.[15]

[15]Recall that OLS estimates of the risk-premium equation are unbiased if (random) measurement error in the survey data is assumed to be the sole source of regression error.

TABLE 4—WEEKLY ONE-MONTH-AHEAD SWISS FRANC RISK-PREMIUM EQUATION (SAMPLE: JANUARY 1987–DECEMBER 1989)

$$i_{t,k}^{\text{SWF}} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t I_t + u_{t,k}$$

Coefficient	Intervention: One-day[a]	One-week[b]	Cumulative[c]
A. I_t *Includes Fed and Swiss National Bank Intervention:*			
β_0	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)
β_1	47.784 (15.435)**	52.623 (15.892)**	51.972 (15.966)**
β_2	0.094 (0.059)	0.027 (0.016)†	0.002 (0.001)†
ρ	0.232 (0.079)**	0.238 (0.079)**	0.276 (0.078)**
DW:	1.99	1.99	2.00
R^2:	0.12	0.12	0.11
B. I_t *Includes Only Swiss National Bank Intervention:*			
β_0	0.002 (0.001)	0.002 (0.001)	0.002 (0.002)
β_1	48.467 (15.635)**	48.749 (15.704)**	43.207 (16.773)**
β_2	−0.291 (0.537)	0.034 (0.118)	0.013 (0.014)
ρ	0.282 (0.079)**	0.269 (0.080)**	0.278 (0.078)**
DW:	2.01	2.01	2.00
R^2:	0.11	0.11	0.11
C. I_t *Includes Only Fed Intervention:*			
β_0	0.002 (0.001)	0.002 (0.001)	0.002 (0.002)
β_1	47.721 (15.408)**	52.754 (15.829)**	51.803 (15.968)**
β_2	0.106 (0.062)†	0.027 (0.016)†	0.002 (0.002)
ρ	0.229 (0.079)**	0.237 (0.080)**	0.276 (0.078)**
DW:	1.98	1.99	2.00
R^2:	0.12	0.12	0.11

Notes: Standard errors are given in parentheses. Entries for ρ report the estimated first-lag correlation coefficient. Number of observations = 156; $k = 30$. Intervention is expressed in millions of dollars.

[a]Intervention variable is measured at the end of the day prior to the survey.

[b]Intervention variable is an accumulated measure between survey forecasts.

[c]Intervention variable is an accumulated measure from the beginning of the sample period.

†Statistically significant at the 10-percent level.

*Statistically significant at the 5-percent level.

**Statistically significant at the 1-percent level.

V. Conclusions

There appear to be statistically significant effects of Fed and Bundesbank intervention on exchange rates through the portfolio channel during our mid-1980's sample period. These results suggest that the consensus view in the early 1980's, that intervention policy is largely ineffective, is no longer supported by the data. Unfortunately, it is not possible to estimate our alternative portfolio-balance model specification with the data used in the earlier studies because survey data on exchange-rate expectations are only available starting in 1982. However, even our results for the sample period 1982–1984, when the Reagan Administration officially opposed intervention in the foreign-exchange market, indicate that cumulative intervention had a statistically significant effect on the risk premium.

Is the statistical significance of intervention also economically important? This calculation depends crucially on one's assumption of how interest rates change in reaction to changes in investors' demands for mark and dollar assets. However, as long as the interest differential does not fully absorb the impact of intervention on the risk premium, our coefficient estimates indicate that foreign-exchange interventions do matter.[16]

Appendix: Variable Definitions and Data Sources

s_t: log of the \$/DM (or \$/SWF) spot exchange rate at time t (Source: DRI/McGraw-Hill [Data Resources Incorporated])

$\hat{s}^e_{t,k}$: log of Money Market Services median k-period-ahead expectation for the \$/DM (or \$/SWF) rate at time t (Source: Money Market Services)

v_t: daily variance of \$/DM (or \$/SWF) exchange-rate changes since the last survey date

$i^{DM}_{t,k}$: euroDM k-period-ahead interest rate at time t (Source: DRI/McGraw-Hill)

$i^{\$}_{t,k}$: eurodollar k-period-ahead interest rate at time t (Source: DRI/McGraw-Hill)

$i^{SWF}_{t,k}$: euroSWF k-period-ahead interest rate at time t (Source: DRI/McGraw-Hill)

I_t: central-bank intervention, in millions of dollars, known at time t[17] (Sources: Board of Governors of the Federal Reserve System; Deutsche Bundesbank; Swiss National Bank)

W_t: wealth; total supply of U.S. and German federal government debt (Sources: U.S. Treasury [*Treasury Bulletin*]; Bundesbank [*Monthly Report*])

x_t: central-bank intervention as a percentage of wealth (I_t / W_t)

NEWS_t: +1 for newspaper[18] reports of official announcements in support of the dollar (excluding intervention announcements) since the last MMS survey date;
−1 for newspaper reports of official announcements against the dollar (excluding intervention announcements) since the last MMS survey date;
0 for no newspaper reports of official exchange-rate policy announcements (excluding intervention announcements)

REPINT_t: +1 for newspaper reports of central-bank intervention in support of the dollar since the last MMS survey date;
−1 for newspaper reports of central-bank intervention against the dollar since the last MMS survey date;
0 for no newspaper reports of central-bank intervention.

[16] See Dominguez and Frankel (1990, 1993b) for calculations of the effect of intervention on the exchange rate under different assumptions about the market's knowledge of official intervention policies.

[17] Intervention variables are known at time t (purchases and sales through the end of day $t-1$) and are defined in terms of number of dollars purchased.

[18] Newspapers included *The Wall Street Journal*, *London Financial Times*, and *The New York Times*.

REFERENCES

Adler, Michael and Dumas, Bernard, "International Portfolio Choice and Corporation Finance: A Survey," *Journal of Finance*, June 1983, *38*, 925–84.

Boothe, Paul, Clinton, Kevin, Côté, Agathe and Longworth, David, *International Asset Substitutability: Theory and Evidence for Canada*, Ottawa: Bank of Canada, February 1985.

Branson, William H., Haltunnen, Hannu and Masson, Paul R., "Exchange Rates in the Short Run: The Dollar–Deutschemark Rate," *European Economic Review*, December 1977, *10*, 303–24.

______ **and Henderson, Dale W.,** "The Specification and Influence of Asset Markets," in Ronald Jones and Peter Kenen, eds., *Handbook of International Economics*, Vol. 2, Amsterdam: North-Holland, 1985, pp. 749–805.

Dickey, David and Fuller, Wayne, "Distribution of the Estimators for Time Series Regressions with a Unit Root," *Journal of the American Statistical Association*, June 1979, *74*, 427–31.

Dominguez, Kathryn M., "Are Foreign Exchange Forecasts Rational? New Evidence from Survey Data," *Economics Letters*, June 1986, *21* (3), 277–82.

______, "Market Responses to Coordinated Central Bank Intervention," *Carnegie-Rochester Conference Series on Public Policy*, Spring 1990, *32*, 121–64.

______, *Exchange Rate Efficiency and the Behavior of International Asset Markets*, New York: Garland, 1992.

______ **and Frankel, Jeffrey A.,** "Does Foreign Exchange Intervention Matter? Disentangling the Portfolio and Expectations Effects," National Bureau of Economic Research (Cambridge, MA) Working Paper No. 3299, March 1990.

______ **and** ______, (1993a) *Does Foreign Exchange Intervention Work?* Washington, DC: Institute for International Economics, 1993.

______ **and** ______, (1993b) "Foreign Exchange Intervention: An Empirical Assessment," in Jeffrey A. Frankel, ed., *On Exchange Rates*, Cambridge, MA: MIT Press, 1993.

Dooley, Michael and Isard, Peter, "A Portfolio-Balance Rational-Expectations Model of the Dollar–Mark Rate," *Journal of International Economics*, May 1982, *12*, 257–76.

______ **and** ______, "The Portfolio Balance Model of Exchange Rates and Some Structural Estimates of the Risk Premium," *IMF Staff Papers*, December 1983, *30*, 683–702.

Dornbusch, Rudiger W., "Exchange Risk and the Macroeconomics of Exchange Rate Determination," in R. Hawkins, R. Levich, and C. Wihlborg, eds., *The Internationalization of Financial Markets and National Economic Policy*, Greenwich, CT: JAI Press, 1983, pp. 3–27.

Engel, Charles M. and Rodrigues, Anthony P., "Tests of International CAPM with Time-Varying Covariances," *Journal of Applied Econometrics*, April–June 1989, *4*, 119–38.

Frankel, Jeffrey A., "The Diversifiability of Exchange Risk," *Journal of International Economics*, August 1979, *9*, 379–93.

______, (1982a) "A Test of Perfect Substitutability in the Foreign Exchange Market," *Southern Economic Journal*, April 1982, *46*, 406–16.

______, (1982b) "In Search of the Exchange Risk Premium: A Six-Currency Test Assuming Mean-Variance Optimization," *Journal of International Money and Finance*, December 1982, *1*, 255–74.

______, "The Dazzling Dollar," *Brookings Papers on Economic Activity*, 1985, (1), 199–217.

______ **and Froot, Kenneth A.,** "Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations," *American Economic Review*, March 1987, *77*, 133–53.

Froot, Kenneth A. and Frankel, Jeffrey A., "Forward Discount Bias: Is It an Exchange Risk Premium?" *Quarterly Journal of Economics*, February 1989, *104*, 139–61.

Giovannini, Alberto and Jorion, Philippe, "The Time-Variation of Risk and Return in the Foreign Exchange and Stock Markets," *Journal of Finance*, June 1989, *44*, 307–24.

Golub, Stephen S., "Foreign-Currency Government Debt, Asset Markets, and the Balance of Payments," *Journal of International Money and Finance*, June 1989, *8*, 285–94.

Henderson, Dale W., "Exchange Market Intervention Operations: Their Role in Financial Policy and Their Effects," in John Bilson and Richard Marston, eds., *Exchange Rate Theory and Practice*, Chicago: University of Chicago Press, 1984, pp. 357–406.

______ **and Sampson, Stephanie,** "Intervention in Foreign Exchange Markets: A Summary of Ten Staff Studies," *Federal Reserve Bulletin*, November 1983, *69*, 830–6.

Kouri, Pentti J. K. and de Macedo, Jorge A. Braga, "Exchange Rates and the International Adjustment Process," *Brookings Papers on Economic Activity*, 1978, (1), 111–30.

Krugman, Paul R., "Consumption Preferences, Asset Demands, and Distribution Effects in International Financial Markets," National Bureau of Economic Research ((Cambridge, MA) Working Paper No. 651, March 1981.

Loopesko, Bonnie, "Relationships Among Exchange Rates, Intervention, and Interest Rates: An Empirical Investigation," *Journal of International Money and Finance*, December 1984, *3*, 257–77.

Mussa, Michael, *The Role of Official Intervention*, Group of Thirty Occasional Papers No. 6, New York: Group of Thirty, 1981.

Nelson, Charles R. and Startz, Richard, "The Distribution of the Instrumental Variables Estimator and Its *t*-Ratio When the Instrument Is a Poor One," *Journal of Business*, January 1990, *63*, S125–40.

Obstfeld, Maurice, "The Effectiveness of Foreign-Exchange Intervention: Recent Experience: 1985–1988," in William Branson, Jacob Frenkel, and Morris

Goldstein, eds., *International Policy Coordination and Exchange Rate Fluctuations*, NBER Conference Volume, Chicago: University of Chicago Press, 1990, pp. 197–246.

Phillips, Peter K. and Perron, Pierre, "Testing for a Unit Root in Time Series Regressions," *Biometrika*, June 1988, *75*, 335–46.

Rogoff, Kenneth S., "On the Effects of Sterilized Intervention: An Analysis of Weekly Data," *Journal of Monetary Economics*, September 1984, *14*, 133–50.

Sims, Christopher A., "Bayesian Skepticism on Unit Root Econometrics," *Journal of Economic Dynamics and Control*, June/September 1988, *12*, 463–74.

Board of Governors of the Federal Reserve System, "Daily U.S. Intervention Data," Washington, DC, various years.

Deutsche Bundesbank, "Indebtedness of the Federal Government, Total," Table 9, *Monthly Report*, various issues.

______, "Daily German Intervention Data," Frankfurt, Germany.

DRI/McGraw-Hill, "Daily Exchange Rate Data (London Close)," DRIFACS database, Lexington, MA: Standard and Poor's Corporation, various years.

Money Market Services, "Foreign Exchange Rate Survey Data," Belmont, CA: Money Market Services, International, various years.

Swiss National Bank, "Daily Swiss Intervention Data," Zurich, Switzerland, various years.

U.S. Treasury, "Total Securities Held by the Public," Table FD-1: Summary of Federal Debt, *Treasury Bulletin*, various issues.